

Brain Integration Programme Elements

At Brain Integration Therapy & Consulting, we evaluate an individual's function using standardised and widely accepted assessment tools and compare the results to established norms by age, grade, or typical functional level. We use these quantifiable baseline levels of function to devise a customised program for a client to use as a springboard to move towards growth and development. We work to integrate functional systems and improve whole-brain timing and communication. Some of the normed and researched components of the brain balancing programme include:

- Primitive reflex training
- Balance exercises
- Gait training
- Vestibular activities
- Eye coordination and perception exercises
- Auditory system training

These activities, coupled with academic engagement and nutritional guidance, performed frequently enough and for a long-enough duration, work to improve brain connectivity and development. This integrative approach helps your child achieve improved learning across the board — academically, physically, socially, and emotionally.



Sensory motor activities

The brain is quite literally built from the bottom up, beginning with basic survival reflexes and progressing towards increasingly sophisticated function. This process starts with early childhood experiences and interaction with the world, and the movement patterns and sensory exploration those experiences provide. Therefore, sensory stimulation and activation of motor systems actually drive development of the brain. This understanding is at the core of everything we do at Brain Balance Achievement Centers. Our program is designed around that fact that it is crucial to improve sensory perception, processing, and motor skills before improvements in learning and self-regulation can truly occur.

Sensory skills involve the tools we have to interpret the world around us, including smell, touch, vision, hearing, and balance. No sensory function works in isolation: All senses are dependent on integration with other sensory functions, which requires an age-appropriate, baseline level of development. Sensory activities address many issues including:

- Auditory perception and processing
- Visual system muscle coordination, perception and processing
- Smell perception and processing
- Touch / nervous system perception and processing
- Vestibular (inner ear / visual system integration)
- Proprioception (perceiving the body's location in space)
- Spatial perception, orientation and directionality

Motor skills are similarly diverse and require integration and coordination in order for an individual to operate at acceptable, age-appropriate levels. Motor skills developed in childhood and utilized throughout life include:

- Primitive and postural reflexes
- Vestibular balance and posture
- Muscle tone, strength, and coordination
- Eye-muscle balance and coordination
- Rhythm and timing
- Bilateral (cross-body) coordination
- Gross and fine-motor skills



Activities to increase academic engagement

The academic component of the Brain Balance program utilizes an approach to learning that goes beyond traditional teaching/tutoring techniques. Targeting specific areas of the brain that are associated with key cognitive functions, our academic program component provides another highly effective tool to stimulate growth and development. Again, we are targeting the root problem, rather than teaching tactics to work around a deficit in order to address the academic learning problem head-on and to help students succeed where they have previously struggled. Utilizing curriculum in a manner that is often overlooked by our schools, we work to enhance listening and reading comprehension, reasoning, information processing and retention, and even social and emotional understanding, raising the bar for what is possible for our students academically as well as socially.

Nutritional coaching

Delivered by a team of registered dietitians well versed in the challenges of feeding kids and families healthy foods, the Balance 360 nutritional approach focuses on educating families and guiding them towards fueling their bodies with the nutrients necessary for building healthy brains and bodies. Balance 360 is designed to fit an individual's lifestyle, needs, and preferences, while improving health and decreasing any inflammation or other detrimental effects of the body's inability to tolerate certain ingredients common in our modern, processed diet. With a focus on fresh, whole foods, Balance 360 provides one more key in our integrated approach to drive the best possible outcomes for every program participant.



Scientific research that supports brain balance approach

Primitive reflex training

Primitive reflexes are suppressed during early development, which allows for the normal emergence of volitional motor activity

The grasp and other primitive reflexes

Published in 2003 in Journal of Neurology, Neurosurgery, and Psychiatry

This review article discusses research on various primitive reflexes, which are reflexive behavioral motor responses that typically emerge during early development and are suppressed during later stages of development to allow for the normal emergence of voluntary motor activity.

Retention of primitive reflexes is linked to difficulties in reading

Primary reflex persistence in children with reading difficulties (dyslexia):

a cross-sectional study

Published in 2007 in Neuropsychologia

This study examined the effects of retained primitive reflexes on the attainment of core literacy skills in children with or without dyslexia (aged 7-9 years old). The results showed that retention of the asymmetric tonic neck reflex was predictive of attainments in reading, spelling, and verbal IQ. There were no differences between the performance of dyslexic and non-dyslexic children on any of the outcome measures. These findings suggest that for many children in mainstream educational programs, the attainment of core educational skills may be affected by the persistence of a brainstem-mediated reflex system that should have been inhibited in the first year after birth.

Prevalence of persistent primary reflexes and motor problems in children with reading difficulties

Published in 2004 in Dyslexia

Studies have shown that some children with reading difficulties have underlying developmental delay, which may be related to the persistence of primitive reflexes. This study investigated the prevalence of persistent primitive reflexes in a typically developing primary school population (aged 9-10 years). The results showed that retention of the asymmetric tonic neck reflex was found in higher levels in children with lower reading abilities compared to those with higher reading abilities. It was also found that there was a significant difference in motor abilities between the lowest and highest reading groups. These findings highlight the persistence of primitive reflexes in children with reading difficulties and provide further evidence of the association between movement difficulties and reading in young children.

Primitive reflex training

Retention of primitive reflexes is associated with attentional problems

Primitive reflexes and attention-deficit/hyperactivity disorder: developmental origins of classroom dysfunction

Published in 2004 in International Journal of Special Education

This study examined overlap of ADHD behaviors and retention of four primitive reflexes — Moro, tonic labyrinthine reflex (TLR), asymmetrical tonic neck reflex (ATNR), and symmetrical tonic neck reflex (STNR) — in boys aged 7-10 years. The results showed that boys diagnosed with ADHD had significantly higher levels of reflex retention than boys without an ADHD diagnosis. The results also indicated both direct and indirect relationships between retention of these primitive reflexes with ADHD symptomatology and mathematics achievement.

Asymmetric tonic neck reflex and symptoms of attention deficit and hyperactivity disorder in children

Published in 2013 in International Journal of Neuroscience

This study examined the extent to which persisting primitive reflexes, specifically the asymmetrical tonic neck reflex (ATNR), is related to symptoms of ADHD in children aged 8-11 years and compared the results in age-matched children without ADHD. The results showed that ADHD symptoms are closely linked to the persistence of ATNR.

Retained primitive reflexes and ADHD in children

Published in 2012 in Activitas Nervosa Superior

This study investigated the role that persisting primitive reflexes, specifically the Moro reflex and Galant reflex, play in ADHD. The results showed that school-aged children with ADHD (8-11 years) had higher levels of persisting Moro and Galant reflexes compared to a control group of age-matched children without ADHD.

Retention of primitive reflexes is correlated with delayed motor development

Persistence of primitive reflexes and associated motor problems in healthy preschool children

Published in 2018 in Archives of Medical Science

This study examined the occurrence of primitive reflexes in typically developing children aged 4-6 years old and analyzed the impact of retained primitive reflexes on psychomotor development. The results showed that retention of primitive reflexes negatively affects psychomotor skills and that the greater the intensity of the retained reflex, the lower the motor efficiency. The researchers recommend routine testing of primitive reflexes in children as well as therapies to facilitate normal integration of reflexes.

Primitive reflex training

Elevated startle reflexes may predict later development of anxiety and depression

Startle modulation in children at risk for anxiety disorders and/or alcoholism

Published in 1997 in Journal of the American Academy of Child & Adolescent Psychiatry

This study aimed to examine the startle reflex as a possible vulnerability marker among 10- to 17-year-old children of parents with anxiety disorders. The researchers found that the magnitude of the startle reflex was elevated in children with a parental history of an anxiety disorder, compared to a control group of children without a parental history of anxiety. These findings suggest that an elevated startle reflex in children and adolescents may predict the later development of anxiety disorders.

Families at high and low risk for depression: a three-generation startle study

Published in 2005 in Biological Psychiatry

Because elevated reactivity of the startle reflex has been shown to be a marker for anxiety disorders, this study investigated the hypothesis that enhanced startle reactivity would also be found in children and grandchildren of individuals with major depressive disorder (MDD). The researchers looked at the magnitude of the startle response in children (second generation) and grandchildren (third generation) of individuals with (high risk) or without (low risk) MDD (first generation). The results showed that the startle response was significantly different between the low- and high-risk groups, with the high-risk group showing increased startle magnitude throughout the fear-potentiated startle test. These findings suggest that increased startle reactivity, previously found in adult patients with anxiety disorders and in children of parents with anxiety disorders, might also constitute a vulnerability marker for MDD.

Training that targets retained primitive reflexes improves sensorimotor skills

Sensorimotor therapy: using stereotypic movements and vestibular stimulation to increase sensorimotor proficiency of children with attentional and motor difficulties

Published in 2009 in Perceptual and Motor Skills

This study examined whether children with attentional and motor difficulties would benefit from sensorimotor therapy using a training program that includes primitive reflex integration along with vestibular stimulation, auditory perceptual stimulation, and gross motor movements. The results showed significant improvement of sensorimotor skills among all three age groups examined: a younger group (7 years old or younger), a middle group (8-10 years old), and an older group (11 years old or older). These findings suggest that a comprehensive training program that includes primitive reflex integration may benefit typically developing children with sensorimotor difficulties and may serve as a complement to regular treatment of developmental coordination disorder, learning disability, or ADHD.

Early Childhood Development Affects Academic Learning later in Life

Early motor development, including balance and coordination and its link to academic and cognitive ability

Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: a systematic review

Published in 2018 in International Journal of Environmental Research and Public Health

This review article evaluated 55 published studies on the associations between motor proficiency and academic performance in math and reading in typically developing school-aged children and adolescents. Significant positive associations were evident between academic performance and components of gross motor proficiency including coordination and agility. Studies also suggest that motor skill interventions in primary school settings may have a positive impact on academic performance in math and/or reading.

Motor skills and exercise capacity are associated with objective measures of cognitive functions and academic performance in preadolescent children

Published in 2016 in PLOS One

This cross-sectional study in 423 typically developing children at the third-grade level found that gross motor skills, including coordination, are positively correlated with academic performance in math and reading comprehension, as well as with several aspects of cognitive function including sustained attention, spatial working memory, episodic and semantic memory, and processing speed.

The relationship between gross motor skills and academic achievement in children with learning disabilities

Published in 2011 in Research in Developmental Disabilities

This study found that 7- to 12-year-old children with learning disabilities showed poorer motor skills compared to age-matched typically developing peers. In addition, a relationship was found between gross motor skills and academic performance in reading in children with learning disabilities. These findings suggest the importance of specific interventions facilitating both motor and academic abilities in children with learning disabilities.

Preschool predictors of school-age academic achievement in autism spectrum disorder

Published in 2017 in Clinical Neuropsychology

This study examined predictors of academic functioning in children with autism spectrum disorder, evaluating them at 2, 4, and 10 years of age. The researchers found that early motor functioning predicted later skills in mathematics, suggesting that interventions targeting motor skills may improve later academic achievement in mathematics in children with autism.

Early Childhood Development Affects Academic Learning later in Life

Relations for children in grades 2, 3, and 4 between balance skills and academic achievement

Published in 1993 in Perceptual and Motor Skills

This study found significant associations between balance skills and academic achievement scores in reading and mathematics in 122 typically developing children in second, third, and fourth grades (7-11 years old).

The role of early fine and gross motor development on later motor and cognitive ability

Published in 2008 in Human Movement Science

This study investigated whether early motor performance (from birth to 4 years old) predicted later cognitive performance of typically developing children once they reached school age (6-11 years old). The results showed a significant predictive relationship for gross motor trajectory and cognitive measures such as working memory and processing speed. The findings add to recent evidence showing a relationship between early motor development and later cognitive function.

The association between the early motor repertoire and language development in term children born after normal pregnancy

Published in 2017 in Early Human Development

This prospective cohort study showed that the early motor repertoire (including motor optimality score and smooth and fluid movements) at 3 and 5 months of age was associated with better expressive language outcome at 4 and 10 years of age in typically developing children born after normal full-term pregnancy. These findings elaborate on what is known about early motor development in that it is tied not only to development of core cognitive functions but also to development of language.



Early Childhood Development Affects Academic Learning later in Life

Close relationship between motor and cognitive ability is explained by brain development

Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex

Published in 2000 in Child Development

This article reviews research that explains, on a neurobiological level, why motor and cognitive development may be fundamentally interrelated. Evidence from neuroimaging, neuroanatomical, and behavioral studies show that this interrelationship is underpinned by a close interaction between the prefrontal cortex (a brain region that plays a critical role in cognitive functioning) and the cerebellum (a key brain region that regulates motor functioning including movement, balance, and coordination).

Inspiring infancy: interrelations between sensory, motor, and cognitive abilities during typical and atypical development

Published in 2016 in Developmental Medicine & Child Neurology

This article is a foreword to a special issue containing 13 review articles discussing recent research on the interrelations between sensory, motor, and cognitive abilities during typical and atypical development in preschool and school aged children, as well as in infancy. The article discusses research showing that cognitive drive facilitates the exploration of motor possibilities and, in turn, the resulting motor behavior generates sensory and cognitive information. Understanding has improved of the complex brain circuitries underlying this interrelated development, with a focus on the cerebellum, striatum, and prefrontal cortex.

Early motor delays, even when mild, can be a precursor to lower academic achievement at later ages

Perinatal morbidity, mild motor delay, and later school outcomes

Published in 2003 in Developmental Medicine & Child Neurology

This study reported that typically developing 4-year-old children who had been born preterm had mild motor delays compared to 4-year-old peers who had been born full term. Furthermore, the group with mild motor delays had lower academic achievement scores and higher rates of school service use at 8 years of age. These findings suggest that early motor delays, even when mild, in typically developing children may negatively impact later academic outcomes.

Sensorimotor stimulation

Sensorimotor deficits are a core feature across different developmental conditions

Sensory-motor deficits in children with developmental coordination disorder, attention deficit hyperactivity disorder and autistic disorder

Published in 2004 in Human Movement Science

This review article discusses research findings that implicates poor sensory-motor integration as a cause of motor problems in developmental disorders such as developmental coordination disorder (DCD) and highlights studies reporting sensory-motor deficits in children with attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD). Based on a critical examination of recent research findings, the researchers stress the importance of poor sensory-motor functioning in discriminating children with different disorders. They suggest that sensory-motor deficits in children with DCD and ASD may provide insight into some of the social difficulties found in these groups of children.

Motor coordination in autism spectrum disorders: a synthesis and meta-analysis

Published in 2010 in Journal of Autism and Developmental Disorders

This review article analyzed the results of 83 studies on motor coordination, gait, arm movements, or postural stability deficits in children with autism spectrum disorder (ASD). The results showed substantial motor coordination deficits in the ASD groups across a wide range of behaviors. These studies suggest that impaired motor coordination is a cardinal feature of ASD and that interventions for this population should target motor coordination.

Deficits in sensorimotor functioning affect cognitive and academic achievement

The canonical relationship between sensory-motor functioning and cognitive processing in children with attention-deficit/hyperactivity disorder

Published in 2009 in Archives of Clinical Neuropsychology

This study found strong correlations between sensory-motor functioning and academic achievement, and between sensory-motor functioning and cognitive processing, in children with ADHD. The strong relationship between sensory-motor skills and higher order cognitive processes indicates that early assessment of sensory-motor skills may be useful in the identification of subsequent deficits in academic performance. The researchers recommended that clinicians should carefully consider the contribution of sensory-motor functioning to academic, behavioral, and emotional problems in children with ADHD.

Sensorimotor stimulation

Sensory (or sensorimotor) enrichment may improve cognitive, academic, behavioral, and sensory functioning

Environmental enrichment as a therapy for autism: A clinical trial replication and extension

Published in 2015 in Behavioral Neuroscience

This randomized controlled trial explored sensorimotor enrichment as a therapy for children with autism spectrum disorder (ASD). Children with ASD, aged 3-6 years old, were randomly assigned to groups that received either daily sensorimotor enrichment along with their standard treatment, or standard treatment alone. The children in the enrichment group participated in sensorimotor exercises that activated different combinations of senses, including olfactory, tactile, thermal, auditory, visual, and motor systems. After 6 months, enriched children showed a decline in atypical sensory responses and autism severity, as well as significant gains in cognitive abilities and receptive language, compared to standard-treatment controls. None of the controls reached an equivalent level of improvement. The researchers also found that even children who received only a subset of sensory enrichment were similar in their improvements to those receiving the full set of enrichment exercises. These findings show that sensorimotor enrichment therapy may be an effective means of treating a range of symptoms in children with ASD.

Catching-up: Children with developmental coordination disorder compared to healthy children before and after sensorimotor therapy

Published in 2017 in PLOS One

This study found that children who have developmental coordination disorder (DCD) caught up with typically developing children in terms of sensorimotor maturity (e.g., balance and vestibular functioning, body-space perception, eye movements, primitive reflexes, gross motor milestones) after completing sensorimotor training for 15 min/day over 36 months (average age = 8 years old). Specifically, the sensorimotor training consisted of vestibular stimulation, tactile stimulation, auditory stimulation, complementary play exercises, gross motor milestones, stereotypical fetal- and infant movements, and sports-related gross motor skills.

Sensory symptoms in autism spectrum disorders

Published in 2014 in Harvard Review of Psychiatry

This review article summarizes the recent research literature on abnormalities in sensory functioning in children with autism spectrum disorder (ASD), including evidence regarding the neurobiological basis of these symptoms, their clinical correlates, and their treatment. Abnormalities in responses to sensory stimuli have been correlated with several other problematic behaviors associated with ASD, including restrictive and repetitive behaviors, self-injurious behavior, anxiety, inattention, and gastrointestinal complaints. The article discussed treatments for sensory symptoms in ASD, which typically involve programs tailored to the needs of the individual and include sensory integration therapy, a sensory diet, and environmental modifications.

Sensorimotor stimulation

Multimodal sensory engagement facilitates learning

Sound facilitates visual learning

Published in 2006 in Current Biology

Numerous studies have shown that practice can improve performance on low-level visual perceptual tasks. However, such learning is characteristically slow, requiring many days of training. This study shows that multisensory audiovisual training facilitates visual learning and results in significantly faster learning than single-sensory visual training. These results show that multisensory interactions can be exploited to yield more efficient learning of sensory information and suggest that multisensory training programs would be most effective for the acquisition of new skills.

An oscillatory neural network model that demonstrates the benefits of multisensory learning

Published in 2018 in Cognitive Neurodynamics

This study uses a computational modeling approach to investigate the mechanisms underlying multisensory processing. The results showed that the use of multisensory channels accelerates learning and recall by up to 80%. These findings are consistent with other recently published results in cognitive science showing that multisensory integration produces greater and more efficient learning.

Balance Exercises

Deficits in balance are associated with attentional and cognitive problems

Balance deficits and ADHD symptoms in medication-naïve school-aged boys

Published in 2014 in Neuropsychiatric Disease and Treatment

This study found that deficits in balance skills were related to ADHD symptoms in school-aged medication-naïve boys (8-11 years old) compared to a control group of boys of the same age. These results provide evidence of a direct relationship between balance deficits and ADHD symptoms, which cannot be attributed to medication or any neurological disease.

Dynamic balance in children with attention-deficit hyperactivity disorder and its relationship with cognitive functions and cerebellum

Published in 2017 in Neuropsychiatric Disease and Treatment

This study looked at a particular component of balance skills — dynamic balance. Developing the ability to maintain balance under dynamic conditions is important in ordinary life because it enables activities to be performed while moving. The researchers found that 7- to 11-year-old children with ADHD and no other neurological conditions had poorer performance on dynamic balancing tasks compared to typically developing controls, and these deficits in dynamic balance were associated with inconsistencies in reaction times. The findings of this study show that poor dynamic balance control is associated with attentional deficits in school-aged children.

Sensorimotor stimulation

Postural and gait performance in children with attention deficit/hyperactivity disorder

Published in 2009 in Gait Posture

Brain imaging studies have shown that the balance deficits seen in children with ADHD could originate at the level of the cerebellum, as these children may show atrophy in regions of the cerebellum associated with gait and balance control. This study investigated static and dynamic balance control in children with ADHD compared to children with chronic surgical cerebellar lesions and age-matched controls. The researchers found that children with ADHD showed mild balance problems that correlated with findings in children with cerebellar lesions. ADHD children also showed abnormalities in a backward walking task and in a paced stepping test. This study showed the presence of balance deficits in children with attentional deficits, which could be mediated by abnormalities in cerebellar regions.

Balance deficit and brain connectivity in children with attention-deficit/hyperactivity disorder

Published in 2017 in Psychiatry Investigation

This study showed that children with ADHD had disturbances of balance and posture compared to matched controls. These disturbance of balance and posture were associated with decreased functional connectivity within brain regions controlling balance — specifically, decreased brain connectivity from the cerebellum to the premotor cortex and anterior cingulate.

Balance training improves multisensory functioning

Task-specific balance training improves the sensory organization of balance control in children with developmental coordination disorder: a randomized controlled trial

Published in 2016 in Scientific Reports

To maintain balance, the inputs supplied by three sensory systems (somatosensory, visual, and vestibular) must be organized and the correct sensory signals need to be selected to generate coordinated movements. Children with developmental coordination disorder (DCD) exhibit deficits in sensory organization, especially in using visual and vestibular inputs and increasing the use of somatosensory inputs to ensure balance. This randomized controlled study found that children with DCD who received two balance training sessions per week for 3 months showed significant improvement in somatosensory function and balance performance compared to controls who did not receive training.

Sensorimotor stimulation

Vestibular Activities

Vestibular functioning is impaired across many developmental conditions

Vestibulo-ocular reflex function in children with high-functioning autism spectrum disorders

Published in 2017 in Autism Research

This study examines vestibular functioning in children with high-functioning autism spectrum disorder (ASD). Specifically, the researchers looked at functioning of the vestibulo-ocular reflex (VOR), where activation of the vestibular system causes eye movement. Essentially, this reflex functions to maintain stable vision during head movements by producing eye movements in the opposite direction of the head movement, thereby preserving images on the center of the visual field. The study found that, compared to typically developing children, children with ASD exhibited an increased ratio of eye velocity to head velocity, indicating a possible lack of inhibitory input from the cerebellum to the brainstem vestibular nuclei in the brain. The ASD group also showed less regular or periodic horizontal eye movements. These findings shed light on alterations in the vestibular system in children with high-functioning ASD.

Children with attention deficit hyperactivity disorder have impaired balance function: involvement of somatosensory, visual, and vestibular systems

Published in 2009 in Journal of Pediatrics

This study examined the ability to use sensory information from the vestibular, somatosensory, and visual systems to maintain balance in school-aged children with ADHD compared with typically developing children. The results showed that children with ADHD had lower scores relating to their use of vestibular, somatosensory, and visual information and showed significant deficits in standing balance performance. These findings suggest that the sensory organization of balance control is impaired in children with ADHD.

Training that targets vestibular functioning leads to improvements in sensorimotor skills

Sensorimotor therapy: using stereotypic movements and vestibular stimulation to increase sensorimotor proficiency of children with attentional and motor difficulties

Published in 2009 in Perceptual and Motor Skills

This study examined whether children with attentional and motor difficulties would benefit from sensorimotor therapy using a multi-component training program, including vestibular stimulation, auditory perceptual stimulation, primitive reflex integration, and gross motor movements. The results showed significant improvement of sensorimotor skills among all three age groups examined: a younger group (7 years old or younger), a middle group (8-10 years old), and an older group (11 years old or older). These findings suggest that a comprehensive training program that includes vestibular training may benefit typically developing children with sensorimotor difficulties and may serve as a complement to regular treatment of developmental coordination disorder, learning disability, or ADHD.

Sensorimotor stimulation

Gait Training

Disturbances in gait are associated with decreased brain functional connectivity and attentional problems

Motor coordination in autism spectrum disorders: a synthesis and meta-analysis

Published in 2010 in Journal of Autism and Developmental Disorders

This review article analyzed the results of 83 studies on gait, motor coordination, arm movements, or postural stability deficits in children with autism spectrum disorder (ASD). The results indicated substantial motor coordination deficits in the ASD groups across a wide range of behaviors. These studies suggest that impaired motor coordination is a cardinal feature of ASD and that interventions for this population should target gait, coordination, and postural deficits.

Visual-Processing Exercises

Visual processing abilities are associated with academic achievement & cognitive performance

Vision and academic performance in primary school children

Published in 2018 in Ophthalmic & Physiological Optics

This study explored the association between vision function and visual information processing measures with academic achievement scores in children at the third-grade level. They found that performance on the Development Eye Movement test, a test of visual information processing, strongly correlated with academic performance in reading, writing, spelling, grammar/punctuation, and numeracy. Other tests of visual information processing, including the Visual Sequential Memory and Symbol Search tests — as well as a standard vision screening test measuring distance visual acuity — also correlated with one or more of these academic categories. These findings highlight the importance of vision function and visual information processing for academic performance in children.

Development of eye-movement control

Published in 2018 in Brain and Cognition

This review article describes research on the maturation of eye movements from reflexive to voluntary during childhood and adolescence and highlights the link between eye movement development and normal brain development. The cognitive control of eye movements — the ability to make precise, voluntary movements of the eyes for visual tracking or fixation on an object — reflects higher cognitive processes such as memory, planning, expectation, and reading. Studies show that children with developmental conditions show impaired control of eye movements and suggest windows of opportunity for intervention.

Sensorimotor stimulation

Visual training leads to improvements in reading and cognitive functioning

Efficacy of dynamic visuo-attentional interventions for reading in dyslexic and neurotypical children: A systematic review

Published in 2019 in Neuroscience & Biobehavioral Reviews

This systematic review of 18 studies evaluated the effectiveness of visuo-attentional interventions aimed at improving reading for children with dyslexia and typically developing children aged 5-15 years. The studies showed that a range of visuo-attentional interventions improved reading fluency and comprehension, reading accuracy and rate, and rate and fluency. These findings show that attentional interventions that incorporate visual training may be effective for improving reading in children with dyslexia.

Training on movement figure-ground discrimination remediates low-level visual timing deficits in the dorsal stream, improving high-level cognitive functioning, including attention, reading fluency, and working memory

Published in 2017 in Frontiers in Human Neuroscience

In addition to deficits in auditory phonological processing, deficits in visual processing have been implicated in many studies on reading disabilities in children. This study investigated the efficacy of a visually based reading remediation intervention to help struggling readers and typically-developing students (2nd and 3rd graders) become more effective readers by improving movement discrimination and visual timing. They found that movement-discrimination training remediated both low-level visual timing deficits and high-level cognitive functioning, including selective and sustained attention, reading fluency, and working memory, for both groups of students (dyslexic or typically developing). These findings suggest that vision-based training can be used to help children with reading difficulties.



Brain connectivity

Altered connectivity in the brain is common across developmental deficits involving sensory, attention, motor, and emotional functioning

Future directions for examination of brain networks in neurodevelopmental disorders

Published in 2018 in Journal of Clinical Child & Adolescent Psychology

Several decades of research have demonstrated that regions of the brain can function as networks. This review article discusses research from numerous studies examining how these brain networks are different under conditions of typical versus atypical development. Key themes that have emerged from these studies include the evolution of segregation and integration of brain networks across normal development and the abnormalities in brain networks in neurodevelopmental disorders. To date, the neurodevelopmental disorders that have been most thoroughly investigated using neuroimaging approaches are autism spectrum disorder and ADHD. Considerable progress has also been made toward characterizing brain network abnormalities that emerge across adolescence in disorders including schizophrenia, anxiety, and depression. The article discusses future directions that would ideally take new developments from cognitive neuroscience and neuroimaging fields and translate them to relevant clinical populations.

Functional connectivity of neural motor networks is disrupted in children with developmental coordination disorder and attention-deficit/hyperactivity disorder

Published in 2014 in NeuroImage: Clinical

This neuroimaging study investigated brain regions that are functionally connected with the primary motor cortex in children with developmental coordination disorder (DCD) with or without ADHD (8-17 years of age). Compared to typically developing controls, children with co-occurring DCD and ADHD evidenced lower functional connectivity between the primary motor cortex and the somatosensory cortices, left supramarginal gyrus, striatum, and amygdala, suggesting poor integration between sensorimotor input, motor execution, and movement regulation. These findings suggest that common neurophysiological substrates may underlie both motor and attention problems.

Neurobiology of sensory overresponsivity in youth with autism spectrum disorders

Published in 2015 in JAMA Psychiatry

More than half of children with autism spectrum disorder (ASD) have sensory overresponsivity (SOR). This study aimed to determine differences in brain responses and connectivity during exposure to mildly aversive sensory stimuli in high-functioning youth with ASD (with or without SOR), compared with typically developing controls (9 to 17 years old). The greatest differences between youth with and without ASD were in response to simultaneous auditory and tactile stimuli. Here, the ASD group showed stronger neural responses in sensory processing regions, including auditory and tactile sensory cortices and the thalamus, and in emotional processing regions, including the amygdala and orbitofrontal cortex. This brain activity was positively correlated with SOR symptoms. In addition, the ASD group without SOR showed a pattern of amygdala downregulation, with negative connectivity between the amygdala and orbitofrontal cortex. These results confirm previous evidence of over-reactive brain responses to sensory stimuli in youth with ASD.

Brain connectivity

You say 'prefrontal cortex' and I say 'anterior cingulate': meta-analysis of spatial overlap in amygdala-to-prefrontal connectivity and internalizing symptomology

Published in 2016 in Translational Psychiatry

This meta-analysis of 46 neuroimaging studies examined brain functional connectivity in three conditions that affect emotional regulation, including anxiety, depression, and PTSD, which are highly comorbid and have common heritable and environmental influences. Out of the 46 studies reviewed, 14 included youth aged 18 years and younger. The researchers observed altered functional connectivity between the amygdala and areas of the frontal cortex almost exclusively in at-risk youth, implying a potential brain substrate of developmental vulnerability. These findings add to accumulating evidence repeatedly showing abnormalities in resting-state functional connectivity between the amygdala and mPFC. These brain regions are part of a core emotion circuitry that has become important to understanding the neural substrates across many different psychiatric conditions in adolescence, including anxiety, depression, and PTSD.

Neural correlates of cognitive control deficits in children with reading disorder

Published in 2019 in Brain Imaging and Behavior

Reading disorder is characterized by deficient phonological processing, but children with reading disorder also have deficits in cognitive control. This study assessed neural activity during the resolution of cognitive conflict on the Simon Spatial Incompatibility task and patterns of resting-state functional connectivity from task control regions in 7- to 12-year-old children with reading disorder compared to their typically developing peers. Relative to typically developing children, those with RD showed reduced functional connectivity from cingulo-opercular seeds to left hemisphere fronto-parietal and temporo-parietal reading-related regions, perhaps reflecting reduced organization of task-control circuits and reduced integration with reading-related regions. In addition, children with reading disorder showed reduced functional connectivity between fronto-parietal and default mode network regions. These findings suggest that altered functioning and connectivity of control circuits in the brain may contribute to cognitive control deficits in children with reading disorder.

Aberrant cerebellar-cerebral functional connectivity in children and adolescents with autism spectrum disorder

Published in 2018 in Frontiers in Human Neuroscience

The cerebellum — important for motor control, coordination, and balance — is one of the brain regions most consistently reported to exhibit neuropathological features in individuals with autism spectrum disorder (ASD). This study found abnormal functional connectivity between the cerebellum and regions of the cerebrum — important for higher-order cognitive functioning — in children and adolescents with ASD compared with typically developing children. Furthermore, these abnormalities in functional connectivity between the cerebellum and cerebrum were correlated with several behavioral measures related to motor, executive, and socio-communicative functions.

Brain connectivity

Different developmental pattern of brain activities in ADHD: A study of resting-state fMRI

Published in 2018 in Developmental Neuroscience

This study examined the developmental patterns of local and global brain activity in children with ADHD compared to typically developing children (aged 7-16 years). The researchers found aberrant functional connectivity between multiple brain networks, such as the default mode network, attention network, and executive control network. Also observed was delayed maturation of brain networks, especially in the default mode network, in the ADHD group. These findings demonstrate the developmental abnormality of brain networks in children and adolescents with ADHD.

Autism and sensory processing disorders: Shared white matter disruption in sensory pathways but divergent connectivity in social-emotional pathways

Published in 2014 in PLOS One

The majority of children with autism spectrum disorder (ASD) demonstrate hyper- or hyporeactivity to sensory input. This study investigated the structural connectivity of specific white matter tracts in the brains of boys with ASD and boys with sensory processing disorder (SPD), relative to typically developing children (aged 8 to 12 years). The results showed that both groups of boys — those with ASD or SPD — demonstrated decreased connectivity relative to controls in parieto-occipital tracts, which are involved in sensory perception and multisensory integration. However, the ASD group alone showed impaired connectivity, relative to controls, in temporal tracts thought to be involved in social-emotional processing. These findings help elucidate the roles of specific brain circuits in neurodevelopmental disorders.

Abnormal functional connectivity in children with attention-deficit/hyperactivity disorder

Published in 2012 in Biological Psychiatry

ADHD is typically characterized by symptoms of inattention and hyperactivity/impulsivity; however, there is increased recognition of reward and motivation deficits in this disorder. The purpose of this study was to map changes in brain functional connectivity density associated with ADHD in a large data set of children with ADHD and typically developing controls. The results showed that children with ADHD demonstrated 15% higher short-range connectivity in regions classically associated with reward and motivation, and 33% lower long-range connectivity in regions classically associated with cognitive processing (parietal cortex). The results also showed lower resting-state functional connectivity strength between reward-motivation and attention networks for children with ADHD than for typically developing controls, which might help explain impairments in cognitive areas (attention/executive) and reward (motivation) in ADHD. Overall, the enhanced connectivity within reward-motivation regions and their decreased connectivity with regions from the default-mode and dorsal attention networks suggest impaired interactions between control and reward pathways in ADHD that might underlie attention and motivation deficits in this disorder.

Brain connectivity

Connectivity in the brains of children can be changed by environmental influences, including experience, training, and practice

A translational framework of educational neuroscience in learning disorders

Published in 2018 in Frontiers in Integrative Neuroscience

This review article discusses how research in the field of neuroscience can inform practical work in educational settings. Neuroscientific findings show that learning disabilities in children are indeed neurobiological and changeable conditions, which helps to dispel still widespread assumptions that performance deficits are due to the learner's laziness, stubbornness, or lack of intelligence. Findings from intervention studies show that deficits and neural dysfunction in learning disabilities can be improved with training and change over time, indicating behavioral and neural plasticity.

Strengthening connections: functional connectivity and brain plasticity

Published in 2014 in Neuropsychology Review

This review article discusses research on the effects of practice and training on intrinsic functional connectivity in the brain. Studies have shown that practice on a range of perceptual, motor, and cognitive tasks changes functional connectivity. For example, in one study discussed, Taubert et al. (2011) compared participants who trained on a dynamic balance task once per week for 6 weeks with a control group who did not practice the balancing task. They found that the trained group exhibited increased "global connectedness" in the bilateral supplementary motor area (SMA), preSMA, and ventral premotor cortex that was absent in the control group. Increased intrinsic functional connectivity with parietal and frontal areas was also observed. These findings underscore the value of training in increasing functional connectivity in the brain.

Developing brain networks of attention

Published in 2016 in Current Opinion in Pediatrics

Attention is a primary cognitive function critical for perception, language, and memory. This article reviews research on the specific brain networks involved in aspects of attention and the development of these networks in childhood. Connectivity between neural areas plays an important role in each network, and several developmental conditions, including autism spectrum disorder and ADHD, involve abnormalities in the connectivity of these brain networks. There is evidence that training can influence the efficiency of these attention networks in the brain. In particular, brain connections can be influenced, at least to some degree, by training that involves repetition of the network or changes of brain state. The researchers conclude that training may be useful in improving function and combatting some forms of pathology.

Brain connectivity

Distinctive heritability patterns of subcortical-prefrontal cortex resting state connectivity in childhood: A twin study

Published in 2018 in Neuroimage

During child development, the ability to regulate emotion and behavior relies heavily on dynamic interactions between three brain regions – the amygdala, prefrontal cortex (PFC), and ventral striatum (VS). This study examined the influence of heritability and the environment on childhood brain connectivity, specifically focusing on connections between these brain regions and other subcortical regions in a relatively large sample of 7-to-9-year-old monozygotic and dizygotic twins. The researchers found that VS-prefrontal cortex connections were best described by genetic and unique environmental factors, whereas amygdala-prefrontal cortex connectivity was mainly explained by environmental influences. Furthermore, connectivity between both the VS and amygdala and ventral anterior cingulate cortex (vACC) showed influences of shared environment, while connectivity with the orbitofrontal cortex (OFC) showed heritability. These findings may inform future interventions that target behavioral and emotional regulation, by taking into account genetic dispositions as well as shared and unique environmental factors. These findings lay the groundwork for understanding how a child's early environment can foster brain connectivity.

Increased resting-state functional connectivity of visual- and cognitive-control brain networks after training in children with reading difficulties

Published in 2015 in NeuroImage: Clinical

This study looked at the effect of a reading-training program on functional connectivity between brain regions involved in visual processing, executive functions, attention, memory, and language in children (8–12 years old) with reading difficulties compared to a typical-reader control group. After training, greater positive correlations were found between the visual-processing component and the components related to executive functions, attention, memory, or language in children with reading difficulties. Training-related increases in connectivity between the visual and attention components and between the visual and executive function components were positively correlated with increased word reading and reading comprehension, respectively. These results suggest that educational training, such as training in reading, may increase functional connectivity in the brains of typically developing children.

Genetic and environmental contributions to functional connectivity architecture of the human brain

Published in 2016 in Cerebral Cortex

This study examined genetic and environmental influences on functional brain connectivity architecture in a large twin sample – 200 twin pairs, including monozygotic and dizygotic pairs. They found that large portions of the interplays between intrinsic connectivity networks are modulated by common environmental effects, highlighting the contribution of environment in the functional architecture of brain connectivity.

Brain connectivity

Increased brain connectivity may be associated with remission of ADHD symptoms

The executive control network and symptomatic improvement in attention-deficit/hyperactivity disorder

Published in 2015 in Cortex

This study investigated whether improved prefrontal top-down control was related to a developmental decrease in ADHD symptoms in adolescents. The researchers found that higher connectivity within frontal regions (anterior cingulate cortex) of the executive control network was related to decreases in ADHD symptoms. Participants with remitting ADHD showed stronger resting-state functional connectivity within this network than controls, while persistent ADHD cases exhibited resting-state functional connectivity strengths intermediate to remittent ADHD cases and controls. These findings support the notion that symptom recovery in ADHD is related to stronger integration of prefrontal regions in the executive control network.

Abnormalities in hemispheric asymmetry are observed in developmental conditions

Interhemispheric asymmetry of regional cerebral blood flow in prepubescent boys with attention deficit hyperactivity disorder

Published in 2001 in Nuclear Medicine Communications

The prefrontal cortex — a brain region critical for cognitive functioning — is asymmetric in both structure and function. In normal individuals, the right prefrontal cortex is activated more than the left during response inhibition. However, this study found the reverse for children with ADHD. Specifically, the researchers examined functional interhemispheric asymmetry during response inhibition in prepubescent boys with ADHD. The boys were divided into three groups according to their level of motor hyperactivity and all performed a response inhibition task. Researchers compared regional cerebral blood flow (rCBF) in the right and left cerebral hemispheres. The results showed that the ADHD group with the highest level of hyperactivity exhibited the most prefrontal left > right rCBF asymmetry and left > right occipitoparietal asymmetry. This observed reversal of functional prefrontal asymmetry in boys with motor hyperactivity supports the hypothesis of right prefrontal cortex dysfunction in ADHD.



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Brain connectivity

Development of cortical asymmetry in typically developing children and its disruption in attention-deficit/hyperactivity disorder

Published in 2009 in Archives of General Psychiatry

Typical development of asymmetries in the human brain has been linked with normal lateralization of motor and cognitive functions, while disruption of asymmetry has been implicated in the pathogenesis of neurodevelopmental disorders such as autism and ADHD. This study examined the development of cortical asymmetry in typically developing children compared to children with ADHD, using longitudinal neuroanatomical data. The results showed that, in right-handed typically developing children, there was an increase in thickness of the right orbitofrontal and inferior frontal cortex with age, which was balanced against an increased left-hemispheric thickness in the occipital cortical regions with age. In children with ADHD, the posterior component of this evolving asymmetry was intact, but the prefrontal component was lost. These abnormalities in the development of prefrontal asymmetry in ADHD is compatible with disruption of prefrontal function in this disorder.

Reduced hemispheric asymmetry of brain anatomical networks in attention deficit hyperactivity disorder

Published in 2018 in Brain Imaging and Behavior

This study investigated alterations in hemispheric white matter in individuals with ADHD, as well as the relationship between these alterations and clinical features of the disorder. The results showed significantly reduced hemispheric asymmetry of global and local integration in individuals with ADHD compared with normal controls, with reduced asymmetric regional efficiency in three brain regions. The researchers also found that the abnormal asymmetry of hemispheric brain anatomical network topology and regional efficiency were both associated with clinical features of ADHD. These findings provide insight into the lateralized nature of hemispheric dysconnectivity in ADHD.

Hemispheric brain asymmetry differences in youths with attention-deficit/hyperactivity disorder

Published in 2018 in NeuroImage: Clinical

This study examined patterns of hemispheric asymmetry differences in a large cohort of children and adolescents with ADHD compared to age-matched typically developing participants. The researchers used imaging techniques to assess both within-hemisphere measures and asymmetries in brain volume, morphology, and white matter microstructure. The results showed alterations in the patterns of hemispheric asymmetry in participants with ADHD across cortical and subcortical volumes, subcortical morphology, and white matter microstructure. These findings are consistent with those of previous studies that have found alterations in aspects of brain asymmetry in ADHD.

Brain connectivity

Abnormal asymmetry in frontostriatal white matter in children with attention deficit hyperactivity disorder

Published in 2016 in Brain Imaging and Behavior

A growing body of research using structural and functional brain imaging and neurocognitive measures of executive and attentional function indicates anomalous asymmetry in the brains of children with ADHD. This study examined the white-matter volume and diffusion properties of frontostriatal tracts, as a function of hemisphere, in young males with ADHD compared to healthy controls (aged 10-18 years). The findings showed that ADHD is associated with anomalous hemispheric asymmetries in both tract volume and underlying white-matter microstructure in major fiber tracts of the frontostriatal system. Specifically, the researchers reported that participants with ADHD did not show the right hemisphere lateralization of volume in the caudate-ventrolateral prefrontal cortex (VLPFC) and caudate-dorsolateral PFC tracts that was evident in controls; however, the ADHD group displayed a pronounced lateralization to the left in the putamen-VLPFC tracts. Putamen-VLPFC white matter that was more strongly lateralized to the left was associated with greater ADHD symptom severity.

Caudate nucleus volume asymmetry predicts attention-deficit hyperactivity disorder (ADHD) symptomatology in children

Published in 2002 in Journal of Child Neurology

Studies comparing children with and without ADHD have found differences in the size and symmetry of the caudate nuclei — brain regions important for learning and attention, along with other cognitive and motor functions. This neuroimaging study further examined the asymmetry of the caudate nuclei in a sample of non-diagnosed children who had varying degrees of inattentive behaviors (aged 7-16 years old). The results showed that a greater degree of right to left caudate volume asymmetry significantly predicted the severity of subclinical inattentive behaviors. This finding is consistent with neuroanatomic models of attention emphasizing lateralized alteration in prefrontal/striatal systems.



Brain connectivity

Brain hemisphere-specific training may improve reading, attention, and sensorimotor performance

The integration of the neurosciences, child public health, and education practice: Hemisphere-specific remediation strategies as a discipline partnered rehabilitation tool in ADD/ADHD

Published in 2013 in Frontiers in Public Health

Some studies have shown that children with ADHD may have abnormal cerebral organization and dysfunctional specialization needed for lateralized processing of language and non-language skills. This study examined a multi-modal treatment program targeting a hypothesized underactive right hemisphere in children with ADHD and its effects on sensory-motor performance and cognitive function related to attentional focus. The program was designed to selectively stimulate skills that were significantly below age or functional level for a given participant and to stimulate the less efficiently performing hemisphere. Each child participated in this multi-modal program that included sensory stimulation, motor training, aerobic strength and conditioning, and academic training. After 36 sessions over a 12-week period, children in the treatment group displayed significant improvements in behavior and in academic domains that require a strong attentional component, including reading, spelling, and writing, compared to controls. The findings suggest that a multi-modal program incorporating hemisphere-specific training may result in functional improvements in children with ADHD.

Effects of visual hemisphere-specific stimulation versus reading-focused training in dyslexic children

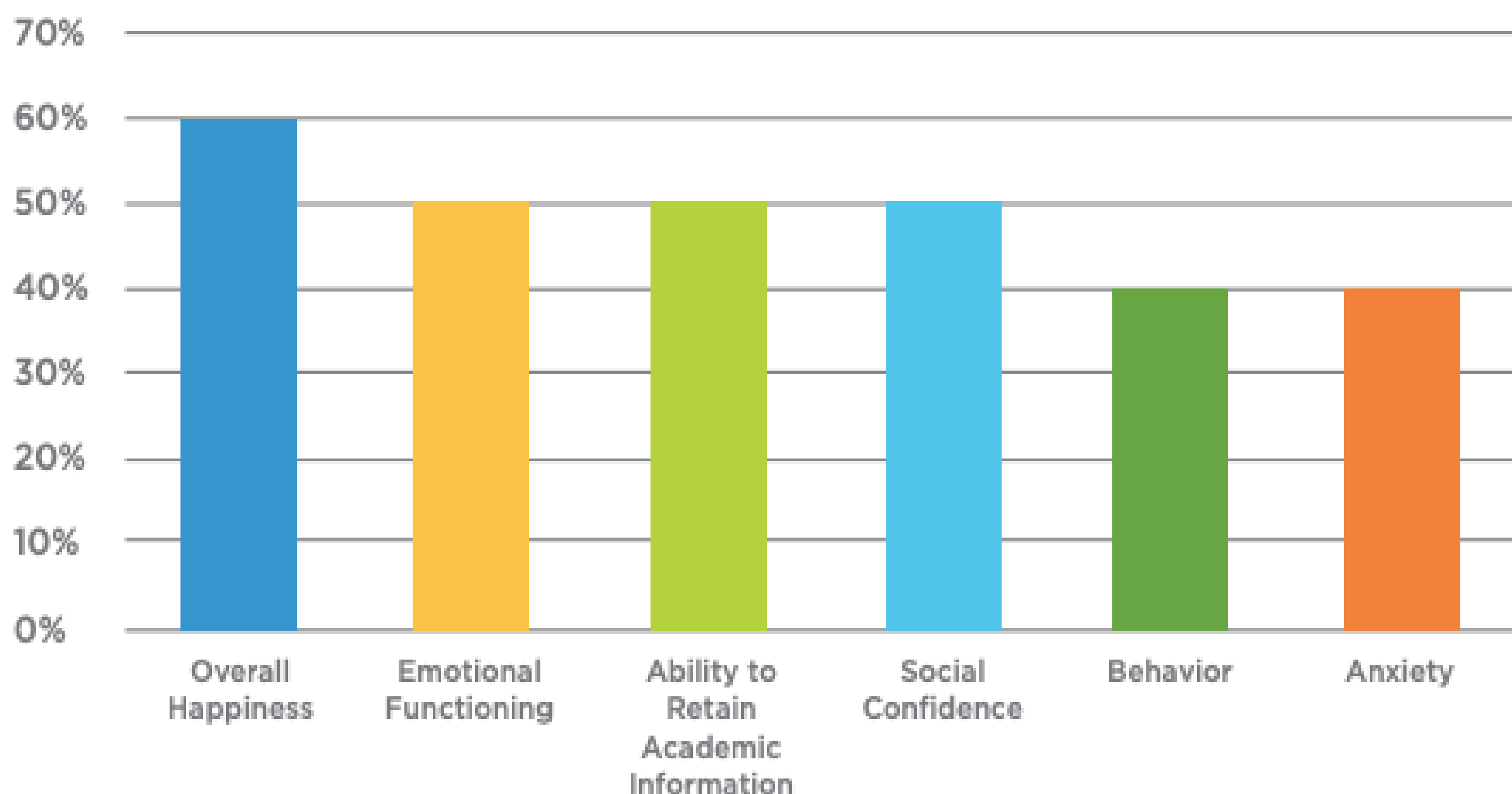
Published in 2006 in Neuropsychological Rehabilitation

This study examined the effects of visual hemisphere-specific stimulation versus a customary, reading-focused training program in children with developmental dyslexia who were treated over 4 months. The researchers found that children who participated in the visual hemisphere -specific stimulation program showed significantly greater improvements in reading accuracy, memory, and phonemic skills than children in the conventional reading training program.



Effects of brain integration programme on emotional, social and academic challenges in participating learners

Median Improvement



Notes: Shown are the data on the percentage improvement in parental responses to this survey item from initial program enrollment to program completion at 5-6 months. Includes data from children (aged 4-17 years) participated in the Brain Balance Program for a duration of 5-6 months (1 hour/day, 3 days/week). This time frame is the most common program length with the most data points.

	Data related to the parental survey item:	No. of parents that provided survey responses
OVERALL HAPPINESS	"Child seems depressed."	428
EMOTIONAL FUNCTIONING	"Child often appears to be unhappy."	630
ABILITY TO RETAIN ACADEMIC INFORMATION	"Child has difficulty remembering academic information from one day to the next."	980
SOCIAL CONFIDENCE	"Child withdraws socially."	689
BEHAVIOR	"Child is argumentative, oppositional, or uncooperative at home."	1,058
ANXIETY	"Child worries a lot."	1,110